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WITNESS my hand this
Fourteenth day of December 2004

LEANNE MYNOTT
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# PROVISIONAL SPECIFICATION

Invention Title: **Valve Operating Apparatus and Method for an Engine**

The invention is described in the following statement:

# VALVE OPERATING APPARATUS AND METHOD FOR AN ENGINE

## FIELD OF THE INVENTION

The present invention relates to a means and method of operating the intake and/or exhaust valves of an internal combustion engine. More particularly the invention relates to use of fluid under pressure to actuate valves during operation of an engine.

## BACKGROUND OF THE INVENTION

Controlling the lift and timing of intake and/or exhaust (poppet) valves in an automotive engine is a necessary aspect of operating an engine. Traditionally, control has been achieved by mechanical systems using a cam to drive the stem of the intake or exhaust poppet valves, while a throttle was used to control the air flow supplied to individual cylinders, as a traditional cam can not adjust the air intake. More recently, it has been known to have a cam which allows the poppet valve lift to be adjusted. However, either approach results in efficiency losses.

Many solutions have been proposed to address the efficiency loss problem. For example, mechanical solutions have been proposed to shift the phase of the camshaft or the lift of the poppet valves to improve efficiency. There have also been hydraulic-mechanical proposals attempting to shift the phase of the camshaft or lift of the valves. These systems tend to be very complicated and not economic to manufacture.

Electro-magnetic solutions using a solenoid to drive the poppet valves have also been proposed, however a solenoid of sufficient size is relatively big, heavy and expensive, and thus not suitable for mass production.

Hydraulic solutions without a camshaft have been proposed, however the complexity of previous attempts to replace a valve train cam and throttle with a hydraulic solution has made them difficult to manufacture and thus uneconomic. The previously proposed hydraulically driven poppet valves generally include both a high and a low pressure fluid supply, requiring major modifications to an existing engine using a camshaft. Hence, the retro-fitting of such devices is expensive because the prior art requires the hydraulic system to be mounted in-line with the longitudinal axis of the poppet valve and as a result, the existing

cylinder head needs extensive changes. Such solutions are generally considered to only be suitable for incorporating into purpose built engines.

The complexity of previous solutions arises partly due to the problem that engine management systems (EMS) do not know the position of poppet valves when an engine is started.

The prior art does not provide a simple, reliable and in particular, efficient, variable engine valve control system. Previously proposed solutions are complex to incorporate into new engines, requiring many alterations. They are also not generally suitable for retrofitting to existing engines that include a camshaft.

As the characteristics of simplicity, reliability and efficiency are important attributes for components of complex machines such as engines, it is a primary object of the present invention to provide a means and method of operating valves that embodies one or more of these characteristics moreso than devices proposed in the prior art. It is a secondary object of the invention to provide a means and method that is relatively adaptable to retro-fitting to an existing engine.

Any discussion of documents, devices, acts or knowledge in this specification is included to explain the context of the invention. It should not be taken as an admission that any of the material formed part of the prior art base or the common general knowledge in the relevant art on or before the priority date of the claims herein.

## SUMMARY OF THE INVENTION

In a first aspect, the present invention provides a valve operating apparatus for an internal combustion engine including:

- A housing;
- A reciprocating piston residing within the housing, the piston connected to one or more poppet valves, each said connection to a poppet valve being external to the housing;
- A first fluid supply path and a first fluid drain path, each path being controllable to supply or drain fluid to/from a first piston end;
- A second fluid supply path and a second fluid drain path; each path being controllable to supply or drain fluid to/from a second piston end;

wherein said piston, in use, is driven between a first position and a second position by controlling said fluid in said supply and drain paths, thereby operating said one or more poppet valves.

In a second aspect, the present invention provides a valve operating apparatus for an internal combustion engine including:

- A housing;
- A reciprocating piston residing within the housing, the piston connected to one or more poppet valves, each said connection to a poppet valve being external to the housing; and
- A first fluid supply path and a first fluid drain path, each path being controllable to supply or drain fluid to/from a first piston end;
- A return spring mounted at said second piston end;

wherein said piston, in use, is driven between a first position and a second position by controlling said fluid in said supply and drain path and the return action of said return spring, thereby operating said one or more poppet valves.

The fluid supply and drain paths of an embodiment of the invention according to either of the above aspects of the invention may be opened and closed to control the flow of said fluid, the opening or closing of each said fluid supply and drain paths may be achieved by one or more solenoid valves or rotary valves, or a combination of these valve types. Controlling the fluid in the supply and drain paths may be achieved via an engine management system controller.

Information regarding the engine speed, desired torque output, fluid and air temperatures and pressures, air humidity and inlet air mass flow and valve positions may be provided to the engine management system controller. The engine management system controller may enable variable lift and timing control of the one or more poppet valves.

The apparatus according to either of the above aspects of the invention may further include a reservoir of high pressure fluid in fluid connection with one or more of said fluid supply path(s).

In a preferred embodiment according to either of the above aspects of the invention, the reciprocating piston is biased to a predetermined position when in an inoperative state, thereby biasing each said poppet valve to a predetermined

position. For the first aspect of the invention, this biasing may be by means of a spring.

Further, according to either of the above aspects of the invention, the reciprocating piston may be partially hollow, thus providing a surface upon which vertical force may act at least at one end of said piston.

In one embodiment, the connection between the piston and the one or more poppet valves is effected by a connector rod fixed to the reciprocating piston. Preferably, connection to the one or more poppet valves allows the one or more poppet valves to spin about their respective longitudinal axes.

In a third aspect, the present invention provides a method of operating valves in an internal combustion engine wherein the internal combustion engine includes a reciprocating piston residing within a housing, said piston being connected to one or more poppet valves externally to the housing, and a first and a second fluid supply and drain path, said paths controllable and in connection with a first and a second end of the reciprocating piston, said first and second piston ends having associated first and second chambers, said method including the steps of:

Opening the first fluid supply path and second fluid drain path and closing the second fluid supply path and first fluid drain path;

Supplying fluid at pressure through the first fluid supply path to the first chamber thereby driving the piston from a first position to a second position;

Opening the second fluid supply path and first fluid drain path and closing the first fluid supply path and second fluid drain path; and

Supplying fluid at pressure through the second fluid supply path to the second chamber thereby driving the piston from the second position to the first position;

Such that one or more poppet valves is driven between a first and a second position through connection with the piston.

In a fourth aspect, the present invention provides a method of operating valves in an internal combustion engine wherein the internal combustion engine includes a reciprocating piston residing within a housing, said piston being connected to one or more poppet valves externally to the housing, and a first fluid supply and first fluid drain path, said paths controllable and in connection with a

first end of the reciprocating piston, said first piston end having an associated first chamber, and a return spring in connection with said reciprocating piston, said method including the steps of:

Opening the first fluid supply path and closing the first fluid drain path;

Supplying fluid at pressure through the first fluid supply path to the first chamber thereby driving the piston from a first position to a second position; and

Opening the first fluid drain path and closing the first fluid supply path thereby allowing the return spring to return the piston from the second position to the first position;

Such that one or more poppet valves is driven between a first and a second position through connection with the piston.

An advantage of the present invention is that engine inefficiency through using a cam and throttle system is reduced by replacing the cam system with a hydraulic alternative.

Another advantage of the present invention is that it is simple in comparison to previously proposed hydraulic systems. The reduced complexity of the invention allows for reduced costs, less mechanical parts, and hence reduced risk of failure and higher reliability. These are very important issues for automotive manufacturers.

Yet another advantage of the present invention is that it may be manufactured to allow for ease of retrofitting. Thus, fewer modifications to an existing automotive engine are required, resulting in reduced fitting time and costs.

## BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention will now be described, without limiting the overall scope of the invention, with reference to the accompanying drawings in which:

Figure 1 shows a schematic of an embodiment of the present invention;

Figure 2 shows a cross-sectional view of a preferred embodiment of the present invention;

Figure 3 shows a cross-sectional view rotated 90 degrees of the embodiment of Figure 2; and

Figure 4 shows an embodiment of a solenoid valve.

## DESCRIPTION OF PREFERRED EMBODIMENT

In a preferred embodiment of the invention, apparatus according to the invention forms part of a hydraulic system, in which, referring to Figure 1, a pressure supply device 20, for example a pump driven by the engine, delivers pressurised fluid from a sump 21 at low pressure to a high pressure reservoir 22. When the high pressure reservoir 22 is full, a pressure relief valve 23 located between the pressure supply device 20 and the high pressure reservoir 22 drains any excess fluid back to the sump 21.

According to the preferred embodiment, when the engine is in use, fluid at pressure is supplied from the high pressure reservoir 22 via a first fluid supply path 3 to a first chamber 11 formed between a first end of the piston 1 and housing 2. A first fluid drain path 5 connecting said first chamber 11 to a sump 21 is closed and the pressure thereby built up in the first chamber 11 causes the piston 1 to be hydraulically driven from a first position to a second position. At the same time, the second fluid supply path 4 is closed and the second fluid drain path 6 is open, allowing any fluid in the second chamber 10 to drain through the second drain path 6 to the sump 21. Motion of the piston 1 assists this draining.

The piston is then returned from the second position to the first position by a similar process, in which fluid at pressure is supplied from the high pressure reservoir 22 via a second fluid supply path 4 to a second chamber 10 formed between a second end of the piston 1 and housing 2. A first fluid drain path 6 connecting said second chamber 10 to the sump 21 is closed and the pressure thereby built up in the second chamber 10 causes the piston 1 to be hydraulically driven from the second position to the first position. At the same time, the first fluid supply path 3 is closed and the first fluid drain path 5 is open, allowing fluid from the first chamber 11 to drain through the first fluid drain path 5 to the sump 21. Again, motion of the piston 1 assists this draining.

Optionally, the first fluid supply path 3 and first fluid drain path 5 may pass through a single port in the housing 2. In the same way, the second fluid supply 4 and drain 6 paths may also pass through a single port.

Movement of the reciprocating piston 1 is translated to one or more poppet valves 7 via a connector rod 9. One or more poppet valve 7 stems are connected to the connector rod 9, the connection 8 being outside the housing 2. Because the connection 8 to the poppet valves 7 is made externally to the housing 2, it is possible to fit the apparatus to a range of existing automotive engines with minimal changes to the cylinder heads. This minimises the re-tooling required to convert a automotive engine from a standard cam system, thereby reducing costs and making retro-fitting of the apparatus more economical and easier to perform. The connector rod 9 of the embodiment shown in Figures 2 and 3 is a straight rod, however a connector of other shapes, such as a U shape or asymmetric shape may be appropriate for particular engines, possibly further reducing the changes required to be made to the cylinder heads.

The connection 8 allows each poppet valve 7 to spin naturally about its longitudinal axis. This is desirable as valve spin during engine operation acts to reduce waste build up in the engine cylinders.

The apparatus may be mounted to the side of the one or more poppet valves 7 rather than in-line, allowing multiple poppet valves 7 to be attached to a connector rod 9. Whilst potentially reducing the number of valve operating devices, a device according to the present invention also requires less height in the cylinder head than a device where the reciprocating piston 1 is in-line with the longitudinal axis of the poppet valve 7 stem.

The opening and closing of the first and second fluid supply and drain paths 3, 4, 5 and 6 is preferably performed by one or more fast acting control valves. In the preferred embodiment, each fast acting control valve is a solenoid valve such as the example depicted in Figure 4. The fast acting control valve may also be a rotary valve or combination valve system. The respective fast acting control valves may be located in the high pressure reservoir 22 or sump 21, or respectively located in the first or second fluid supply or drain paths 3, 4, 5 and 6. By controlling the first and second fluid supply and drain paths 3, 4, 5 and 6 open or closed, movement of the reciprocating piston 1 is controlled. In turn, through the connector rod 9, movement of the one or more poppet valves 7 is controlled.

In a preferred embodiment, the solenoid valves are controlled by an electronic control device, which in turn are controlled by an Engine Management

System (EMS). In this respect, sensors would provide information to the electronic control device or the EMS, including information about the engine's speed, the driver's desired torque output (from an accelerator pedal sensor), the fluid temperatures and pressures, the valve positions, inlet air temperature, pressure and humidity and inlet air mass flow metering. Sensors to provide such information are generally used in modern Engine Management Systems. Information about the hydraulic system would also be detected, for example, the hydraulic fluid pressure would be sensed by a sensor placed in connection with the fluid supply path(s). The electronic control device or EMS would then use the information provided by sensors to adjust the poppet valve 7 lift and timing.

An apparatus according to the present invention allows for increased engine efficiency, and control of the apparatus enables the lift and timing of the poppet valves 7 to be controlled in a variable manner, responding to engine requirements. The precise control also allows the poppet valve(s) 7 to be smoothly stopped without crashing onto the respective valve seat(s).

In a preferred embodiment, a positioning spring 12 returns the piston 1 to a predetermined known position and thus the one or more poppet valves 7 to a predetermined known position when the engine is not in use. This has the advantage of further reducing the complexity of control components required, as it is not necessary to determine the poppet valve starting position when an engine is started. A benefit of having a positioning spring is that the position at which the poppet valve is held when the engine is inoperative is known and hence the position at start up is known. Thus, this approach represents a straightforward approach to determining poppet valve 7 position, further simplifying the apparatus and hence increasing its reliability, and ease of manufacture.

A benefit of having a high pressure reservoir 22 of fluid is that the engine may be started without difficulty as there is no time delay to build up pressure, as may occur when a pump alone is used.

In a preferred embodiment, the piston 1 may be formed with partially hollow ends, as shown in the embodiment of Figures 2 and 3. Holes in the walls of the hollow ends allow the entry of fluid into a chamber 10 or 11 formed between the piston 1 and housing 2. Such an arrangement should substantially decrease the risk of the piston 1 being momentarily jammed in the housing 2.

However, the piston need not be hollow, but of any geometry which presents a surface, which, in conjunction with the relevant chamber, allows the fluid to work upon the piston in the direction of its longitudinal axis.

In an alternative embodiment, the second chamber 10 and fluid supply / drain paths 4, 6 may be replaced by a return spring (not shown). Fluid supplied to the first chamber 11 works against the return spring to drive the piston 1 from the first to the second position and thus drives the one or more poppet valves 7. When the first fluid supply path 3 is closed and the first fluid drain path 5 is opened, the return spring returns the piston 1 from the second to the first position. Hence, when the apparatus is not in use, the return spring will bias the piston 1 to a predetermined position, obviating the need for a positioning spring 12. As previously discussed, a predetermined poppet valve 7 position when starting the engine has the advantage of further reducing the complexity of control components required. It will be recognised by those skilled in the art that the return spring could be located at various positions. For example, the return spring could be located at one end of the reciprocating piston 1, residing within the housing 2. Alternately, the return spring could be mounted outside the housing, for example on the poppet valve 7, or attached to the connector rod 9.

In a method of operating valves in an internal combustion engine wherein the internal combustion engine includes a reciprocating piston 1 residing within a housing 2, the piston 1 being connected 8 to one or more poppet valves 7 externally to the housing, and a first and a second fluid supply 3, 4 and drain 5, 6 path, said paths controllable in connection with a first and a second end of the reciprocating piston, said first and second piston ends having associated first 11 and second 10 chambers, the method includes the steps of:

Closing the second fluid supply path 4 and supplying fluid from the high pressure reservoir 22 via the first fluid supply path 3 to the first chamber 11 formed between the first end of the piston 1 and housing 2, and

Closing the first fluid drain path 5 connecting said first chamber 11 to a sump 21 while the second fluid drain path 6 is open allowing any fluid in the second chamber 10 to drain through the second drain path 6 to the sump 21, motion of the piston 1 assisting this draining.

The building up of pressure in the first chamber 11 causes the piston 1 to be hydraulically driven from a first position to a second position. The piston is then returned from the second position to the first position by a similar process, in which fluid at pressure is supplied from the high pressure reservoir 22 via a second fluid supply path 4 to a second chamber 10 formed between a second end of the piston 1 and housing 2. A first fluid drain path 6 connecting said second chamber 10 to the sump 21 is closed and the pressure thereby built up in the second chamber 10 causes the piston 1 to be hydraulically driven from the second position to the first position. At the same time, the first fluid supply path 3 is closed and the first fluid drain path 5 is open, allowing fluid from the first chamber 11 to drain through the first fluid drain path 5 to the sump 21. Again, motion of the piston 1 assists this draining.

In another preferred embodiment, the present invention provides a method of operating valves in an internal combustion engine wherein the internal combustion engine includes a reciprocating piston 1 residing within a housing 2, said piston 1 being connected 8 to one or more poppet valves 7 externally to the housing2 , and a first fluid supply 3 and first fluid drain 5 path, said paths controllable and in connection with a first end of the reciprocating piston, said first piston end having an associated first chamber 11, and a return spring (not shown) in connection with said reciprocating piston 1, the method including the steps of:

Opening the first fluid supply path 3 and closing the first fluid drain path 5;

Supplying fluid from the high pressure reservoir 22 via the first fluid supply path 3 to the first chamber 11 formed between the first end of the piston 1 and housing 2. The building up of pressure in the first chamber 11 causes the piston 1 to be hydraulically driven from a first position to a second position, such that one or more poppet valves 7 is driven between a first and a second position through connection with the piston 1.

Opening the first fluid drain path 5 and closing the first fluid supply path 3 allows the return spring to return the piston 1 from the second position to the first position. This allows fluid from the first chamber 11 to drain through the first fluid drain path 5 to the sump 21. Motion of the piston 1 assists this draining.

As the present invention may be embodied in several forms without departing from the spirit of the essential characteristics of the invention, it should

be understood that the above described embodiments are not to limit the present invention, but rather should be construed broadly within the spirit and scope of the present invention as defined in the appended claims. Various modifications and equivalent arrangements are intended to be included within the spirit and scope of the present invention.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A valve operating apparatus for an internal combustion engine including:
   - A housing;
   - A reciprocating piston residing within the housing, the piston connected to one or more poppet valves, each said connection to a poppet valve being external to the housing;
   - A first fluid supply path and a first fluid drain path, each path being controllable to supply or drain fluid to/from a first piston end;
   - A second fluid supply path and a second fluid drain path, each path being controllable to supply or drain fluid to/from a second piston end;

   wherein said piston, in use, is driven between a first position and a second position by controlling said fluid in said supply and drain paths, thereby operating said one or more poppet valves.

2. A valve operating apparatus according to claim 1 further including a reservoir of high pressure fluid in fluid connection with one or more of said fluid supply paths.

3. A valve operating apparatus according to claim 1 or 2 wherein said reciprocating piston is biased to a predetermined position when in an inoperative state, thereby biasing each said poppet valve to a predetermined position.

4. A valve operating apparatus according to claim 3 wherein said reciprocating piston is biased by means of a spring.

5. A valve operating apparatus according to any one of the preceding claims wherein said reciprocating piston is partially hollow, said hollow providing a surface upon which vertical force may act at least at one end of said piston.

6. A valve operating apparatus according to any one of the preceding claims wherein a connector rod fixed to the reciprocating piston connects to one or more poppet valves.

7. A valve operating apparatus according to any one of the preceding claims wherein said connection to the one or more poppet valves allows the or each poppet valve to spin upon its longitudinal axis.

8. A valve operating apparatus according to any one of the preceding claims wherein said fluid supply and drain paths are opened and closed to control the flow of said fluid, said opening or closing of each said fluid supply and drain paths achieved by one or more solenoid valves or rotary valves, or a combination of said valve types.

9. A valve operating apparatus according to any one of the preceding claims wherein controlling said fluid in said supply and drain paths is achieved via an engine management system controller.

10. A valve operating apparatus according to claim 9 wherein said engine management system controller enables variable lift and timing control of said one or more poppet valves.

11. A valve operating apparatus for an internal combustion engine including:

- A housing;
- A reciprocating piston residing within the housing, the piston connected to one or more poppet valves, each said connection to a poppet valve being external to the housing; and
- A first fluid supply path and a first fluid drain path, each path being controllable to supply or drain fluid to/from a first piston end;
- A return spring mounted at said second piston end;

wherein said piston, in use, is driven between a first position and a second position by controlling said fluid in said supply and drain path and the return action of said return spring, thereby operating said one or more poppet valves.

12. A valve operating apparatus according to claim 11 further including a reservoir of high pressure fluid in fluid connection with said fluid supply path.

13. A valve operating apparatus according to claim 11 or 12 wherein said reciprocating piston is biased to a predetermined position when in an inoperative state, thereby biasing each said poppet valve to a predetermined position.

14. A valve operating apparatus according to claim 13 wherein said reciprocating piston is biased by means of a spring.

15. A valve operating apparatus according to any one of the preceding claims 11 to 14 wherein said reciprocating piston is partially hollow, said hollow providing a surface upon which vertical force may act at least at one end of said piston.

16. A valve operating apparatus according to any one of the preceding claims 11 to 15 wherein a connector rod fixed to the reciprocating piston connects to one or more poppet valves.

17. A valve operating apparatus according to any one of the preceding claims 11 to 16 wherein said connection to the one or more poppet valves allows the or each poppet valve to spin upon its longitudinal axis.

18. A valve operating apparatus according to any one of the preceding claims 11 to 17 wherein said fluid supply and drain paths are opened and closed to control the flow of said fluid, said opening or closing of each said fluid supply and drain paths achieved by one or more solenoid valves or rotary valves, or a combination of said valve types.

19. A valve operating apparatus according to any one of the preceding claims 11 to 19 wherein controlling said fluid in said supply and drain paths is achieved via an engine management system controller.

20. A valve operating apparatus according to claim 19 wherein said engine management system controller enables variable lift and timing control of said one or more poppet valves.

21. A method of operating valves in an internal combustion engine wherein the internal combustion engine includes a reciprocating piston residing within a housing, said piston being connected to one or more poppet valves externally to the housing, and a first and a second fluid supply and drain path; said paths controllable and in connection with a first and a second end of the reciprocating piston, said first and second piston ends having associated first and second chambers, said method including the steps of:

- Opening the first fluid supply path and second fluid drain path and closing the second fluid supply path and first fluid drain path;
- Supplying fluid at pressure through the first fluid supply path to the first chamber thereby driving the piston from a first position to a second position;
- Opening the second fluid supply path and first fluid drain path and closing the first fluid supply path and second fluid drain path; and
- Supplying fluid at pressure through the second fluid supply path to the second chamber thereby driving the piston from the second position to the first position

Such that one or more poppet valves is driven between a first and a second position through connection with the piston.

22. A method of operating valves in an internal combustion engine wherein the internal combustion engine includes a reciprocating piston residing within a housing, said piston being connected to one or more poppet valves externally to the housing, and a first fluid supply and first fluid drain path, said paths controllable and in connection with a first end of the reciprocating piston, said first piston end having an associated first chamber, and a return spring in connection with said reciprocating piston, said method including the steps of:

- Opening the first fluid supply path and closing the first fluid drain path;
- Supplying fluid at pressure through the first fluid supply path to the first chamber thereby driving the piston from a first position to a second position; and

- Opening the first fluid drain path and closing the first fluid supply path thereby allowing the return spring to return the piston from the second position to the first position;

Such that one or more poppet valves is driven between a first and a second position through connection with the piston.

23. A camless hydraulic valve train device substantially as hereinbefore described with reference to any one of the embodiments shown in the accompanying Figures.

**DATED** this 28th day of November 2003

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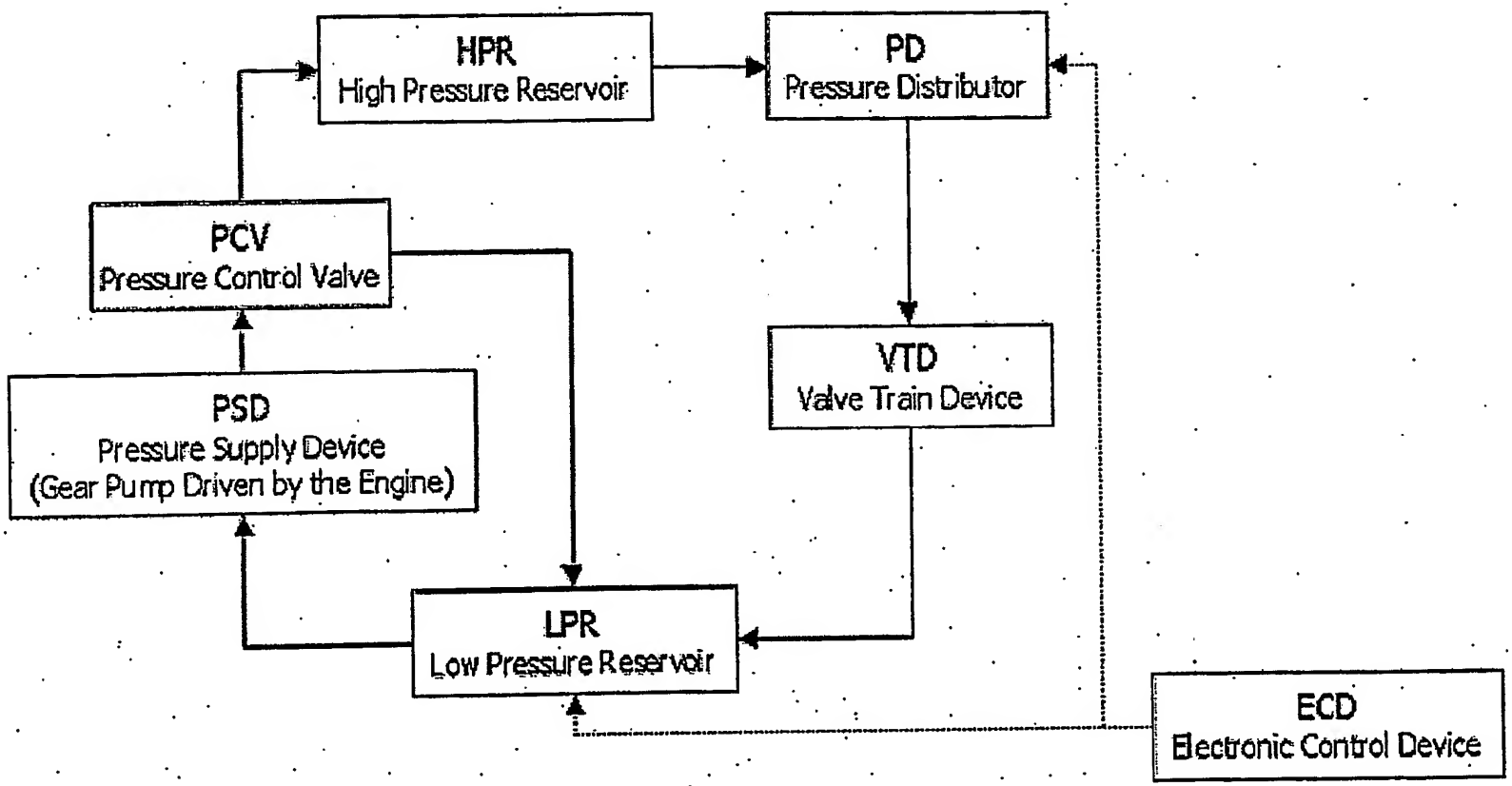
HPR
High Pressure Reservoir
PD
Pressure Distributor
PCV
Pressure Control Valve
VTD
Valve Train Device
PSD
Pressure Supply Device
(Gear Pump Driven by the Engine)
LPR
Low Pressure Reservoir
ECD
Electronic Control Device

Figure 1

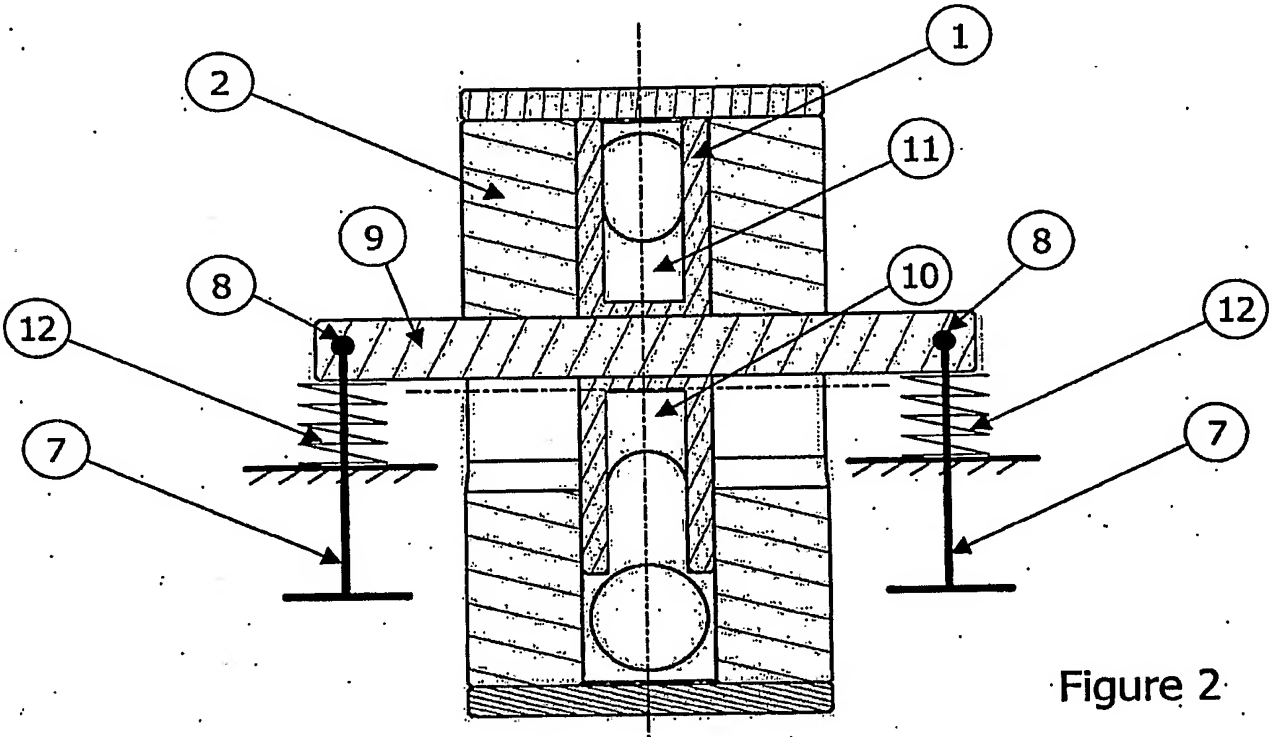


Figure 2

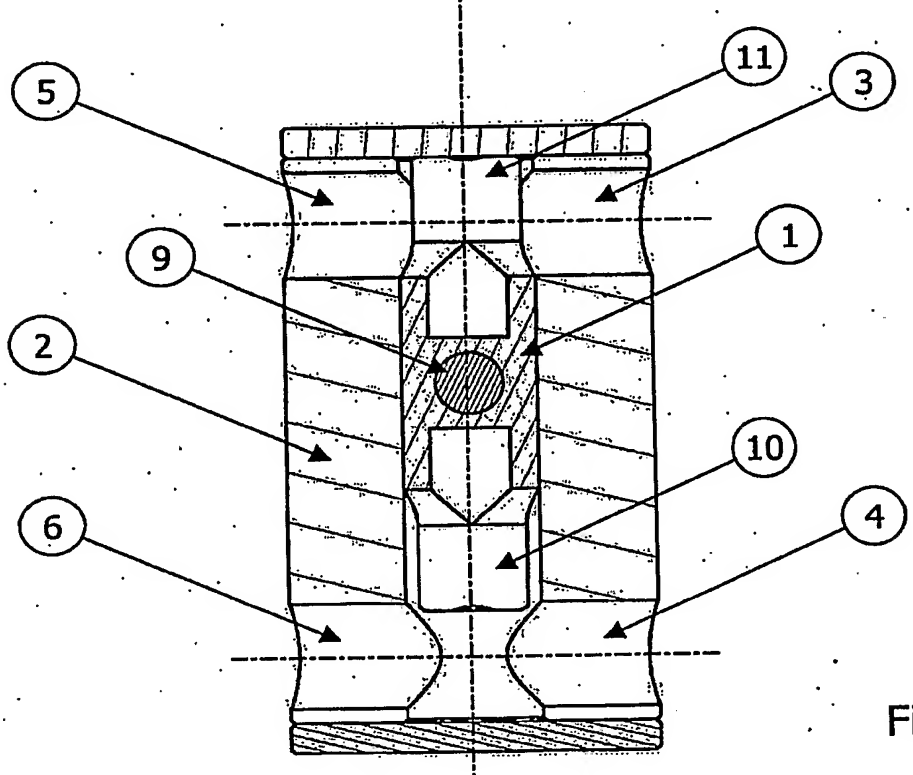


Figure 3

# Fast Reacting Control Valve (FRCV)

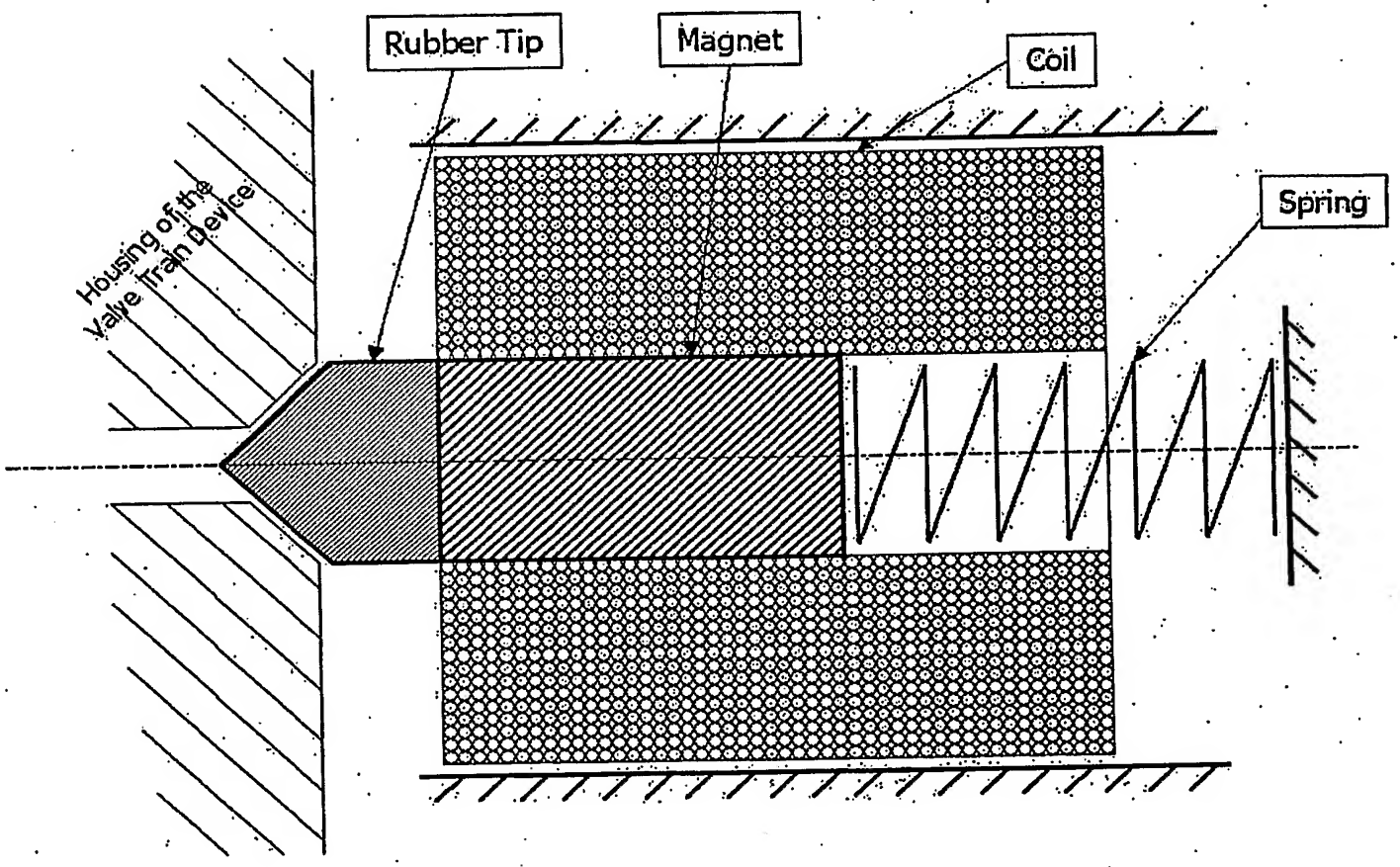


Figure 4